# Front Resolving Observational Network with Telemetry (FRONT)

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## LONG-TERM GOALS

We are developing an observation and prediction system for a dynamically complex region of the coastal ocean. Our long-term goal is to implement and test a data-assimilative observation system that mitigates effects of undersampling, and allows forecasting of physical and biological fields. Data-assimilative models (physical and biological) will provide an integral part of the system. The models will assimilate data from a variety of in situ and remote sensors. A wireless communications network will telemeter data to shore in real time.

## OBJECTIVES

We are installing the Front Resolving Observational Network with Telemetry (FRONT) on a portion of continental shelf south of the eastern end of Long Island, New York (Figure 1A, below). Historical observations indicate that variable bathymetry and strong tides interact with energetic wind- and buoyancy-forced motions to produce recurring fronts. For example, Figure 1A shows SeaWiFS chlorophyll concentration (yellow high, blue low) with a sharp gradient in the middle of the FRONT site (the square subdomain). Our objective is to develop and test the observation system in this complex dynamical regime.

# Report Documentation Page

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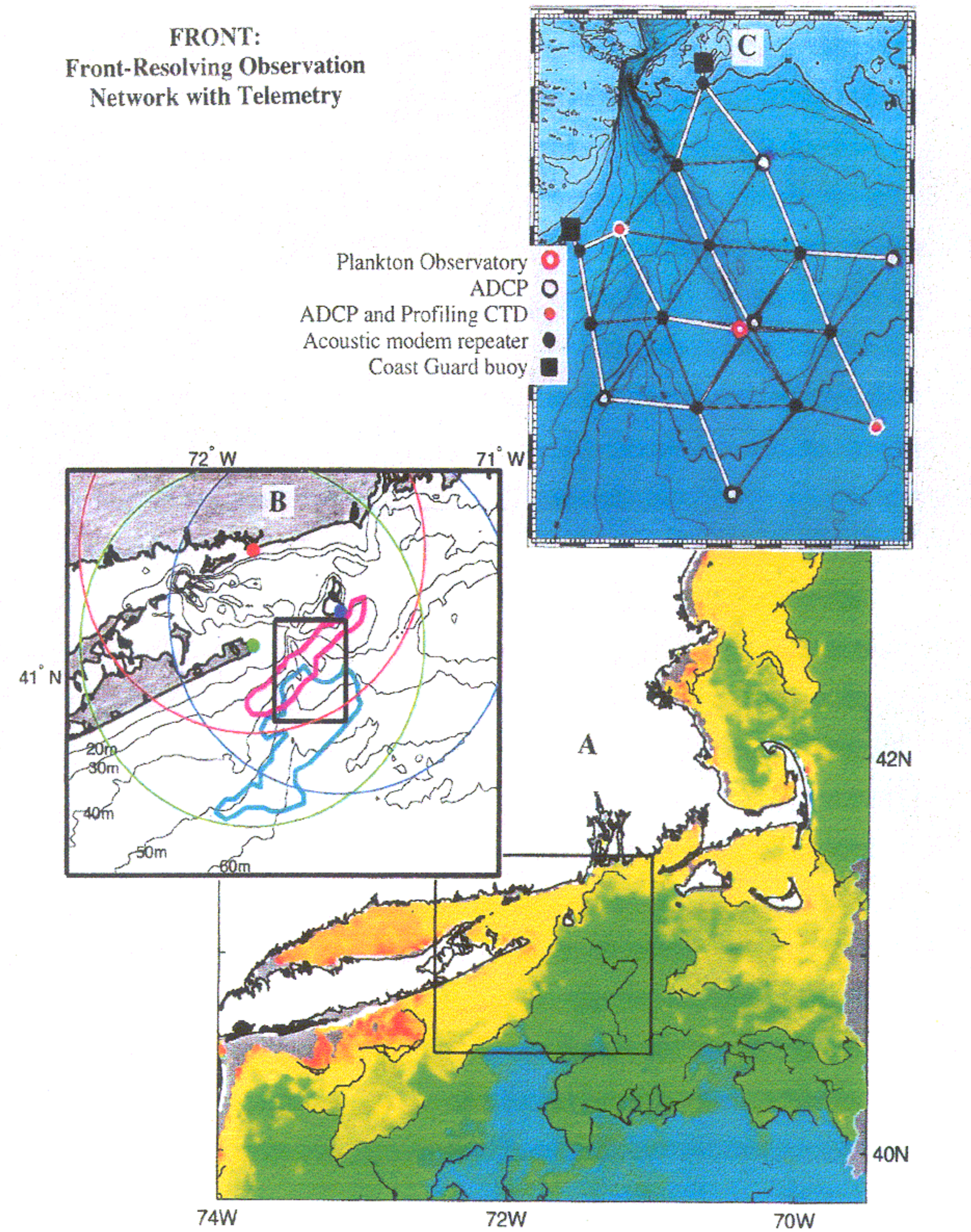


***Figure 1: Three different magnifications of the FRONT site. A: SeaWiFS image. B: Bathymetry contours with CODAR range circles. C: In situ array with sensor locations.***

Technical objectives include coordination and telemetry of real-time data streams from a combination of in situ instruments including ADCPs, profiling CTDs, and an Autonomous Vertically Profiling Plankton Observatory (AVPPO). The array will sample the smaller domain within Figure 1B. Figure 1C (upper right) shows this smaller domain along with sensor and modem locations, and interconnecting acoustic

paths. The blue and magenta contours in Figure 1B show regions where fronts occur with high probability in July (blue) and January (magenta) based on 12 years of AVHRR data.

Shore-based CODAR will provide real-time measurement of surface current. Circles in Figure 1B represent regions of coverage for the 3 stations. Satellite data will provide large-scale coverage of sea-surface temperature and color.

We are setting up a high-resolution version of the MIT general circulation model (MITgcm) for the square region in Figure 1B. Our objective is to comprehensively address dynamics in the region of strong frontal activity. We also anticipate a fascinating interaction between the fluid mechanics and the biogeochemistry of the fronts.

## APPROACH

Data telemetry and instrument control will be accomplished with a wireless underwater communications network. The network features multiple acoustic modems connected in a topology that can tolerate failure or loss of individual elements. Joe Rice of Space and Naval Warfare Systems Center at San Diego (SSC-SD) is working toward this goal. Rice is a PI on the FRONT team with an independent award. Dan Codiga (University of Connecticut) is coordinating the physical oceanographic instrumentation with the Navy's acoustic network.

Scott Gallager, Heidi M. Sosik, and Cabell S. Davis (all at Woods Hole Oceanographic Institution) will be deploying the AVPPO, integrating it into the acoustic network, and analyzing and preparing the data for integration into the biological assimilative model.

John Marshall (Massachusetts Institute of Technology) and Sonya Legg (Woods Hole Oceanographic Institution) are working with Philip Bogden to set up the MIT model for the frontal environment. We will use MITgcm together with its tangent linear, adjoint, and open-boundary capability for data assimilation. Marshall's group at MIT has put enormous effort into the development of non-hydrostatic ocean models that can operate across the scales of motion that are the focus of FRONT. Legg, in particular, has been developing the open-boundary capabilities in idealized studies of boundary mixing associated with critical-angle internal-wave reflection off sloping bathymetry.

The high-resolution non-hydrostatic model will be embedded within an even larger scale barotropic inverse model of the entire New York Bight and lower Gulf of Maine. Bogden is working with a post-doctoral researcher to provide accurate tidal and sub-tidal boundary conditions for MITgcm. This will provide an efficient and computationally economical first step in assimilating the real-time data streams into the more dynamically complex MITgcm.

Mick Follows (MIT), in collaboration with biologists Gallager, Sosik, and Davis at WHOI, and Petra Stegmann (University of Rhode Island), will embed an appropriate regional ecosystem model within the frontal model of Legg and Bogden. With the combined modeling effort we will synthesize the physical and biological data to advance our understanding of the biological interactions on frontal scales.

Remotely sensed surface current maps from CODAR will provide an important supplement to the in situ array. Don Barrick and Belinda Lipa (both with CODAR Ocean Sensors, Ltd.) will assist in the improvement of signal-processing algorithms for using CODAR. This will help CODAR become an integral part of the assimilative models.

Jim O'Donnell (UConn) and Dave Hebert (URI) will coordinate ship surveys that are designed to provide high resolution verification and testing of the observation system in regions of strong frontal activity. O'Donnell is developing a new instrument array designed to resolve the small-scale frontal features that will remain undersampled by the moored instruments and unresolved by the models.

Verification and testing activities include turbulence measurements by FRONT partners at University of Rhode Island, and the Naval Undersea Warfare Center in Newport, Rhode Island. These activities will test the accuracy of the model's sub-grid scale parameterizations.

The United States Coast Guard Research and Development Center is providing substantial supplementary support for the project. This includes a series of surface-drifter deployments in the FRONT region to be coordinated by Jennifer Dick (USCG).

## WORK COMPLETED

Two field programs in the first year exercised the underwater data telemetry system. The first occurred during November of 1999. During this period, sound speed profiles were upward refracting, and modem communications rarely exceeded 1 kilometer. Results also showed severe degradation of transmission quality during strong wind events.

The second field program took place in the spring of 2000. Large-scale surveys showed that sound-speed profiles were highly variable during this period, with a shallow region of downward refraction immediately adjacent to the surface. This may account for improved acoustic modem ranges during these tests, often exceeding 3 kilometers.

Dan Codiga of UConn worked with Joe Rice of the Space and Naval Warfare Systems Center, San Diego (a FRONT partner with a different award number) to develop bottom-mounts containing ADCP, modem, and batteries. The collaboration included a gateway technology for relaying acoustic modem communications to a Bell Atlantic server on the Internet, and then to offices at UConn. The US Coast Guard has provided critical support for using existing navigational aids as instrument platforms for the gateway.

Model development is continuing. MITgcm, the general circulation model developed at by John Marshall at MIT, has successfully been adapted to a coastal setting. MITgcm is running in prognostic mode in the FRONT region, resolving tides and associated variability with time scales up to a month. Mick Follows (MIT) is leading the coordination of ecosystem and physical models.

## RESULTS

Substantial technological advances have been made in real-time data telemetry and modeling. According to the model, nonlinearly rectified tidal flow occasionally reaches 20 cm/sec in this domain. Velocities at tidal frequencies are much larger, and agree well with observed tides south of Block Island. This result is not surprising. However, Figure 2 shows the result of a passive tracer experiment 10 days into the model run. The tracer reproduces many of the front-like features observed in satellite temperature and color. Although such features are generally associated with density variation and buoyancy effects, these results come from a homogeneous model run. In other words, the tidal residual flow appears to control

the qualitative structure of the front-like features that motivated this study. This result is preliminary, and data analyses are underway to verify the dynamical mechanisms involved.

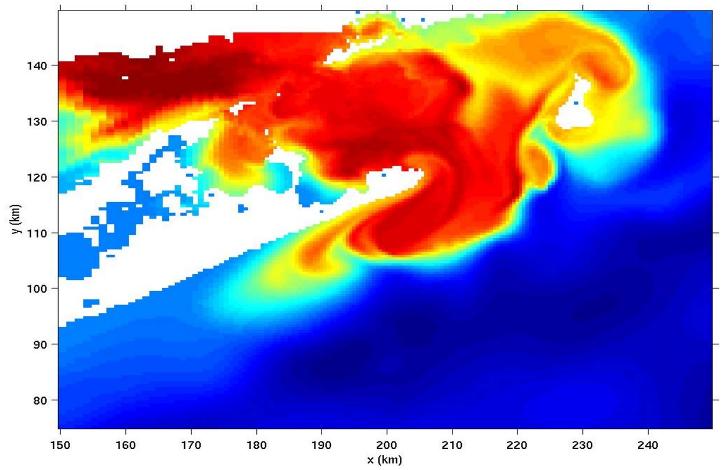


***Figure 2. Result of a passive tracer simulation. The model is unstratified and forced only by tides. This image occurs 10 days after spin up from a horizontally uniform tracer distribution with blue at the surface and red at depth.***

## IMPACT/APPLICATIONS

Individual components of the FRONT project should be transportable to other regions. But the dynamical complexity of the FRONT site provides a special challenge to this kind of observation system. If we can develop predictive capabilities in this complex regime, then we should be able to translate the results to prediction of currents, the acoustic channel, and biology in the vicinity of coastal density fronts.

## TRANSITIONS

The FRONT experiment schedule includes planned outages during which the fielded network may be used by SSC-SD to test prototype deployable sensors for surveillance, and other autonomous undersea devices, including mobile network nodes such as AUV's. The concomitant knowledge of the ocean structure provided by the FRONT system will allow SSC-SD to diagnose the relationships between network performance and the environment.

## RELATED PROJECTS

FRONT is part of the National Oceanographic Partnership Program (NOPP). The project includes participation of scientists at University of Rhode Island (URI), National Undersea Warfare Center (NUWC) in Newport, Rhode Island, an SSC-SD. Dave Hebert (URI), Ed Levine (NUWC) and Joe Rice (SSC-SD) are the lead PI's on these related Awards.

## PUBLICATIONS


Bogden, P. S., and FRONT Partners. (2000) Front resolving observational network with telemetry (FRONT). AGU Ocean Sciences, Spring Meeting, San Antonio, Texas.

Codiga, D., J. Rice, and P. S. Bogden. (2000) Real-time delivery of subsurface coastal circulation measurements from distributed instruments using networked acoustic modems. Oceans 2000 Conference. Providence. Rhode Island.